US009471210B1

(12) **United States Patent**
Fram et al.

(10) **Patent No.: US 9,471,210 B1**
(45) **Date of Patent: Oct. 18, 2016**

(54) **SYSTEMS AND METHODS FOR INTERLEAVING SERIES OF MEDICAL IMAGES**

(71) Applicant: **DR Systems, Inc.**, San Diego, CA (US)

(72) Inventors: **Evan K. Fram**, Paradise Valley, AZ (US); **Murray A. Reicher**, Rancho Santa Fe, CA (US); **Steven M. Greim**, Oceanside, CA (US); **John J. Schumacher**, San Diego, CA (US)

(73) Assignee: **D.R. Systems, Inc.**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/502,055**

(22) Filed: **Sep. 30, 2014**

Related U.S. Application Data

(63) Continuation of application No. 12/857,915, filed on Aug. 17, 2010, now Pat. No. 8,879,807, which is a continuation of application No. 11/268,261, filed on Nov. 3, 2005, now Pat. No. 7,885,440.

(60) Provisional application No. 60/625,690, filed on Nov. 4, 2004.

(51) **Int. Cl.**

G06F 3/00	(2006.01)
G06F 3/0484	(2013.01)
G06F 3/0482	(2013.01)

(52) **U.S. Cl.**
CPC ***G06F 3/04845*** (2013.01); ***G06F 3/0482*** (2013.01)

(58) **Field of Classification Search**
CPC G06K 9/36; G06F 3/04845; G06F 3/048
See application file for complete search history.

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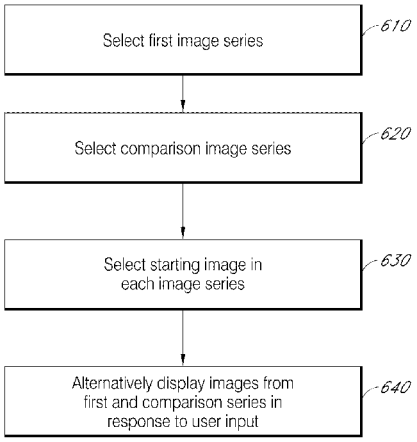
Primary Examiner — Chan Park
Assistant Examiner — Mia M Thomas
(74) *Attorney, Agent, or Firm* — Knobbe, Martens, Olson & Bear, LLP

(57) **ABSTRACT**

After selecting two or more image series for comparison, images of the image series are interleaved so that they are alternatively displayed in a comparison pane on a display device. In one embodiment, after one or more image series are selected for comparison, an interleaved image series is created containing each of the images of the one or more selected image series, or, alternatively, the interleaved image series comprises links to the images arranged in the interleaved pattern. If differences exist in the images of the multiple image series, these differences may be more easily detectable as the display device cycles between the images. Comparison of images in an interleaved image series may be more advantageous if the images of each selected image series are of a common anatomical area, common image size, and the images are in the same order.

18 Claims, 9 Drawing Sheets



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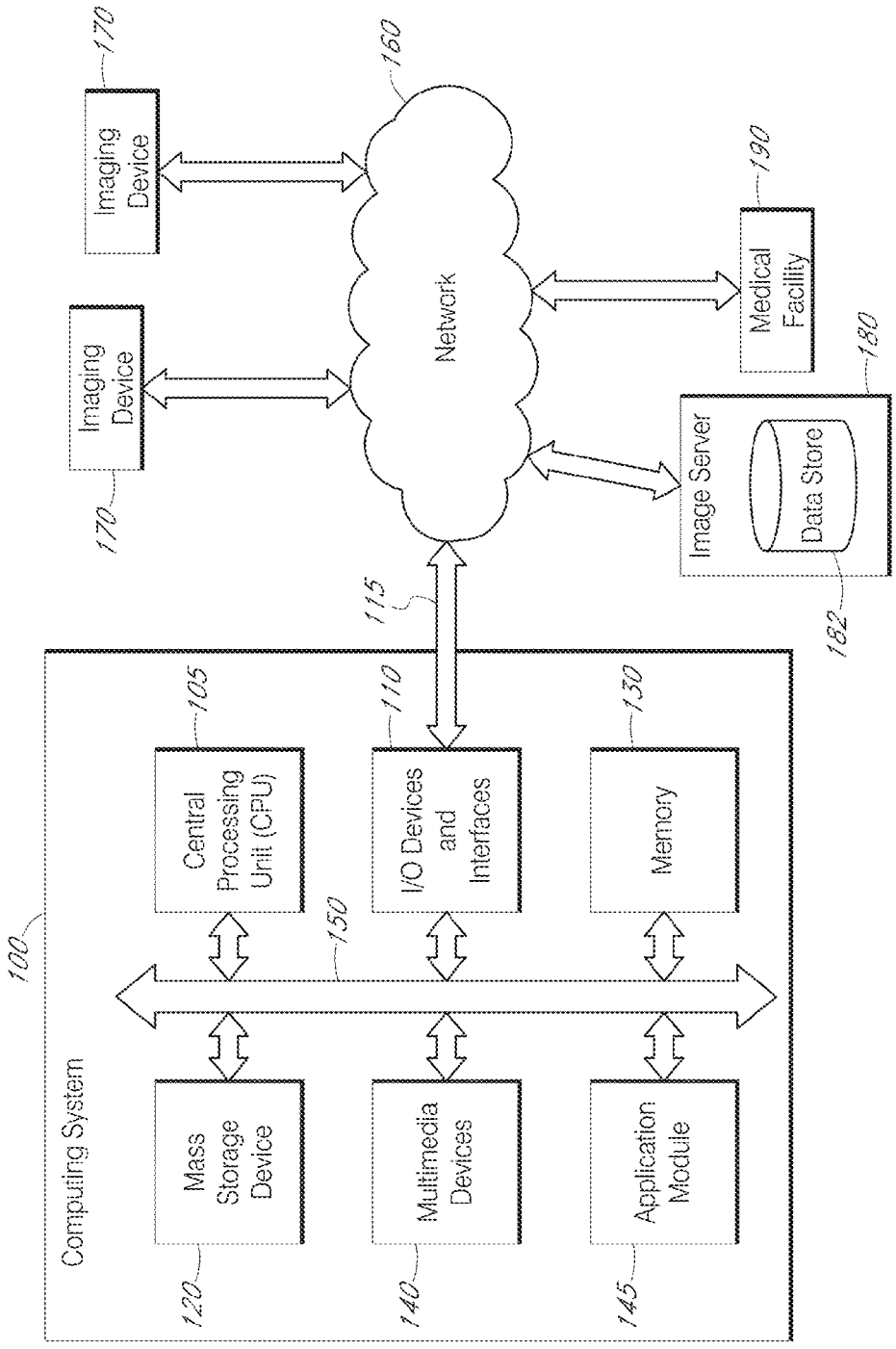
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Image Server
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180
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FIG. 1

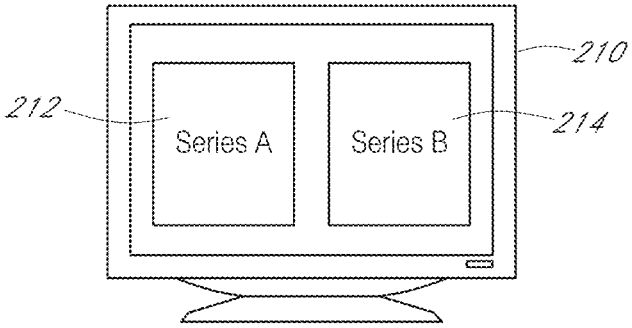
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FIG. 2

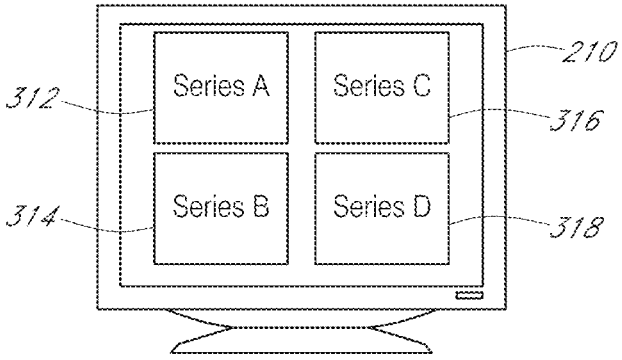
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FIG. 3

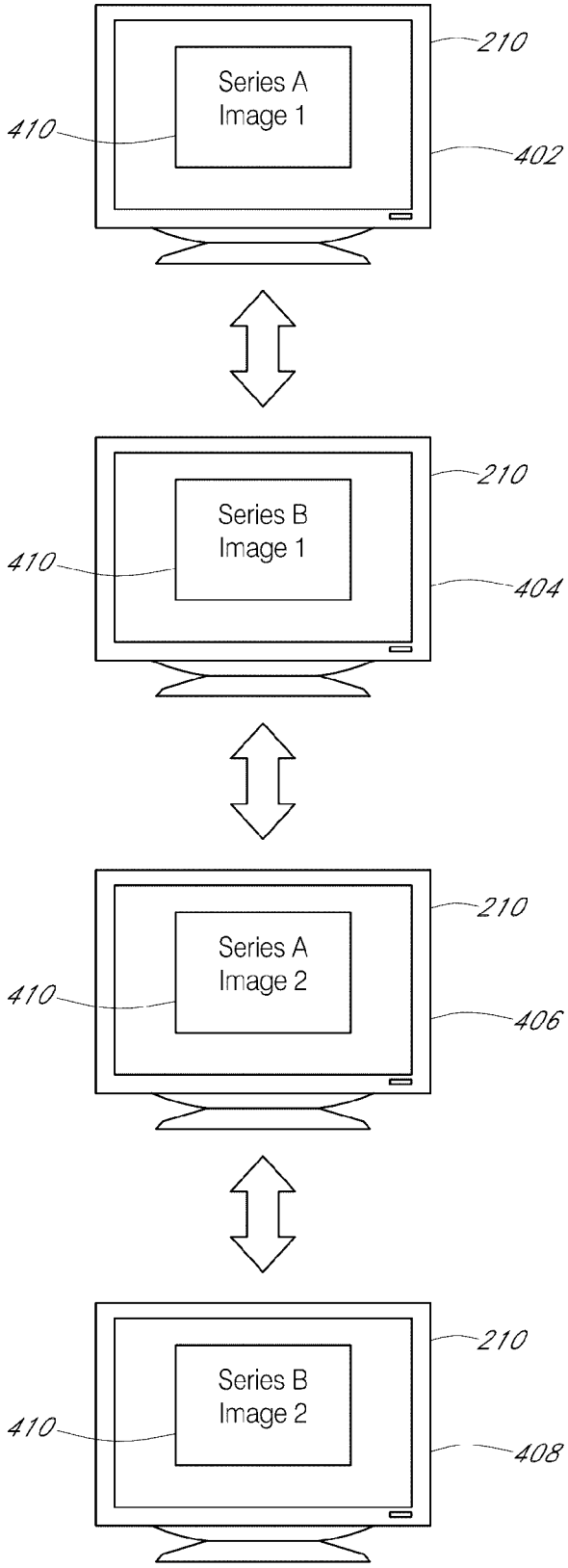
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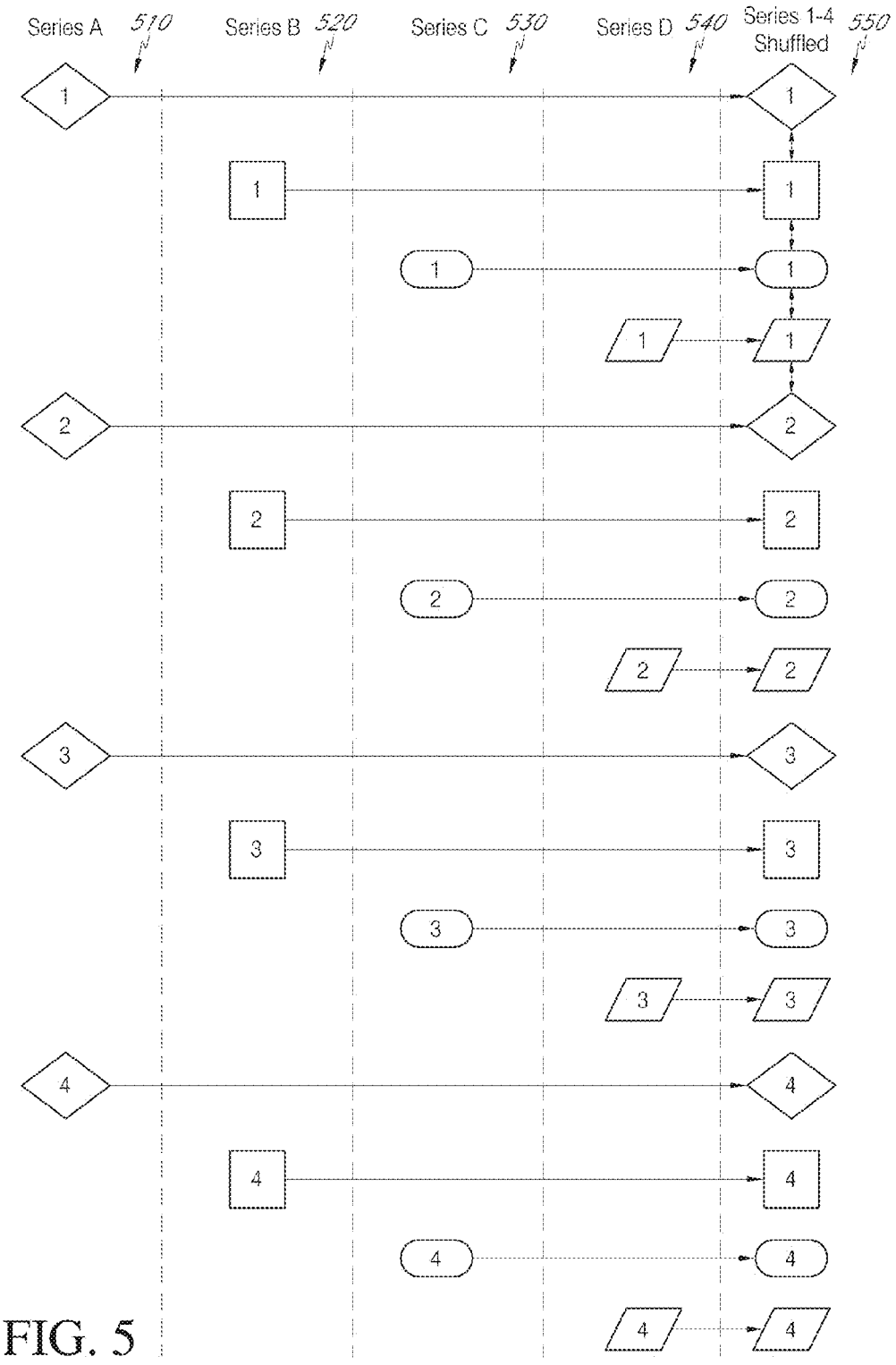
FIG. 4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Series D
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Series 1-4 Shuffled
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2
3
4

FIG. 5

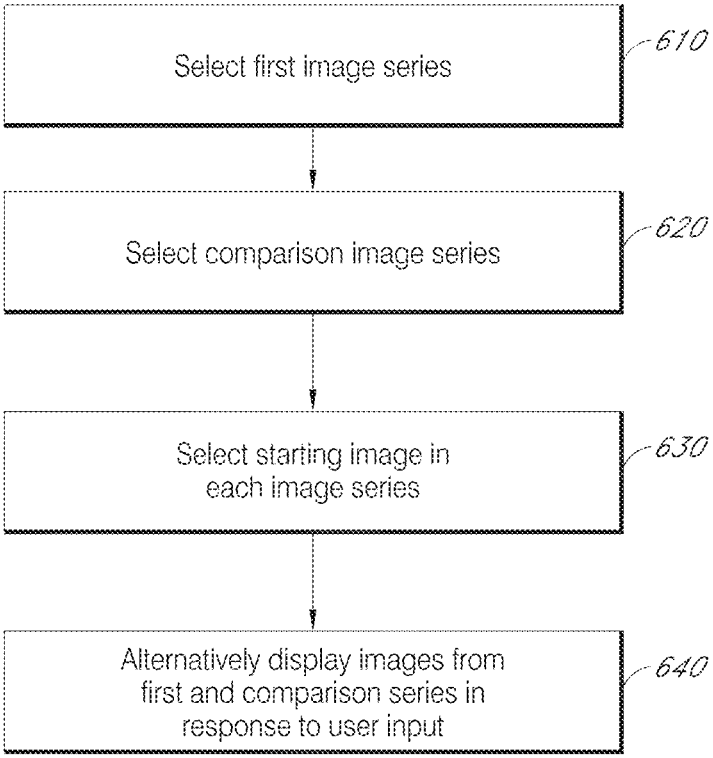

Select first image series
610
Select comparison image series
620
Select starting image in each image series
630
Alternatively display images from first and comparison series in response to user input
640

FIG. 6

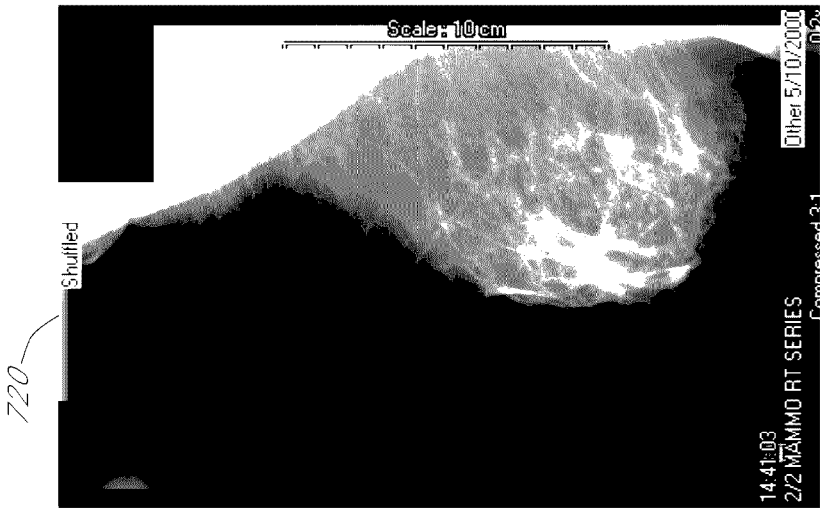

Scale: 10cm
Shuffled
Other 5/10/2000
0.2x
14:41:03
2/2 MAMMO RT SERIES
720

FIG. 7B

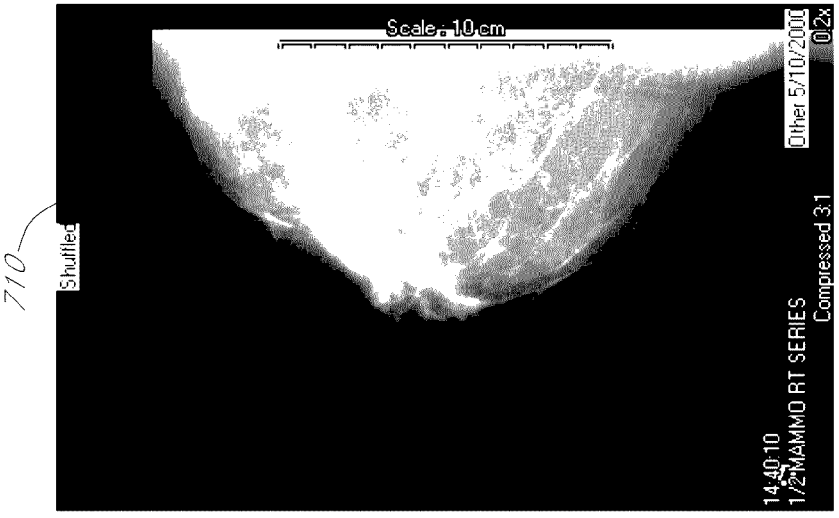

Scale: 10cm
Shuffled
Other 5/10/2000
0.2x
14:40:10
1/2 MAMMO RT SERIES
Compressed 3:1
710

FIG. 7A

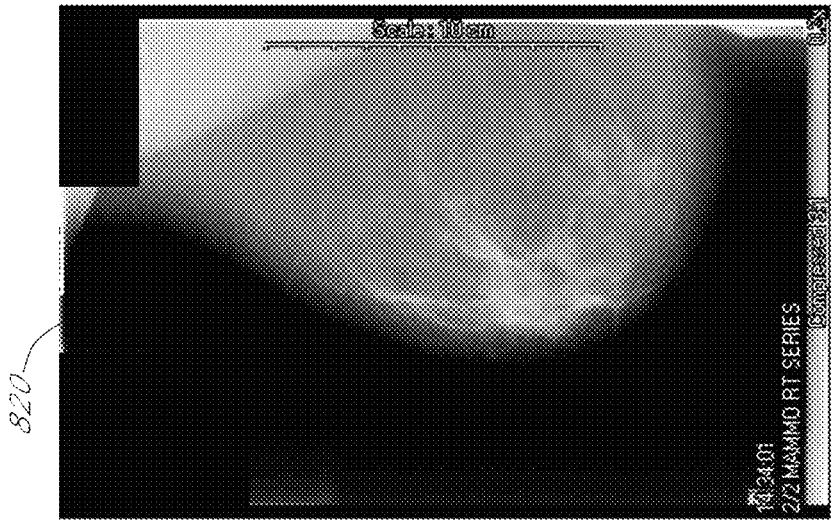

820
Scale: 10 cm
14:34:01
2/2 MAMMO RT SERIES
Compressed 3:1

FIG. 8B

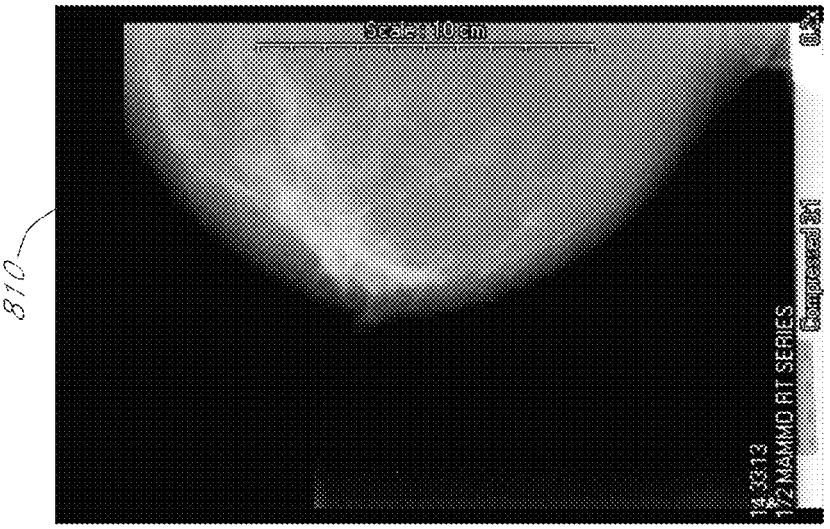

810
Scale: 10 cm
14:33:13
1/2 MAMMO RT SERIES
Compressed 3:1

FIG. 8A

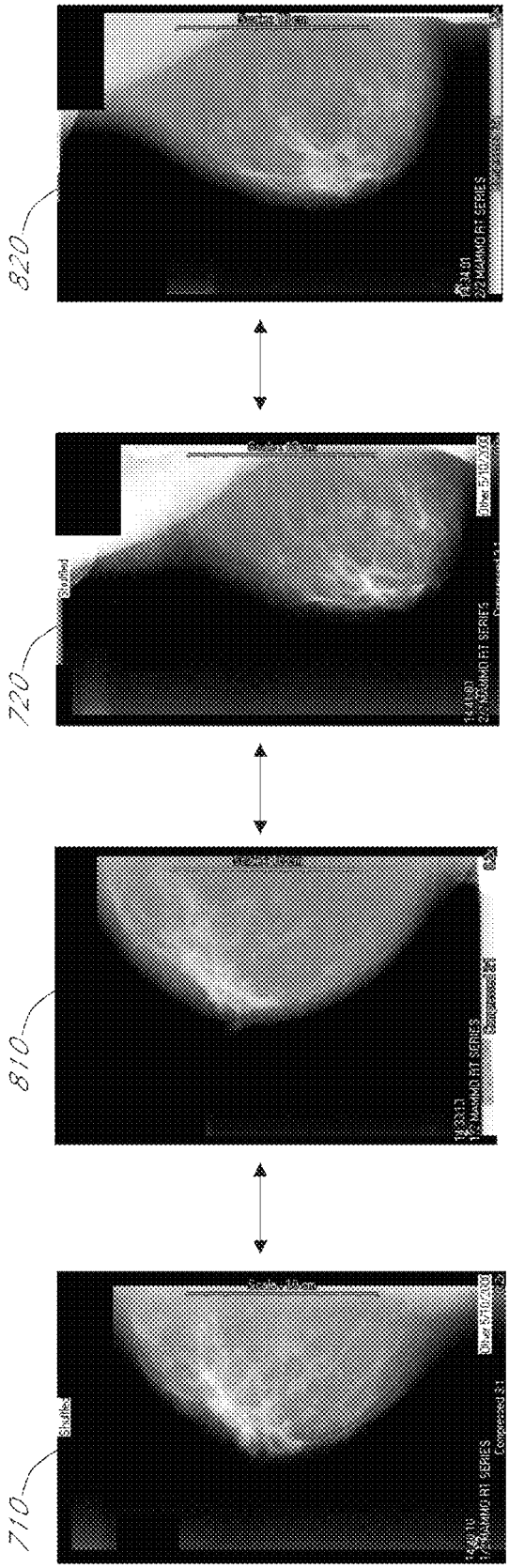


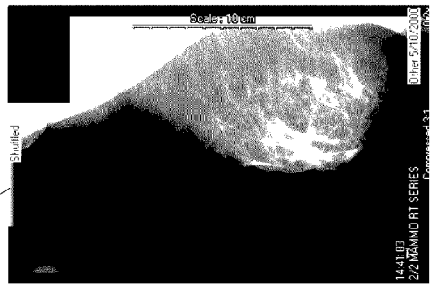
FIG. 9A

FIG. 9B

FIG. 9C

FIG. 9D

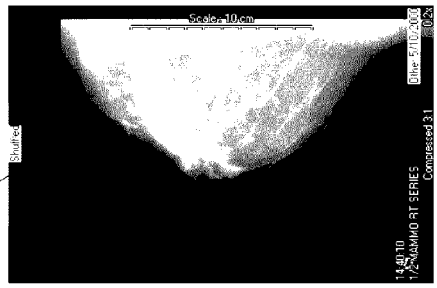
820



720

FIG. 12

810



710

FIG. 11

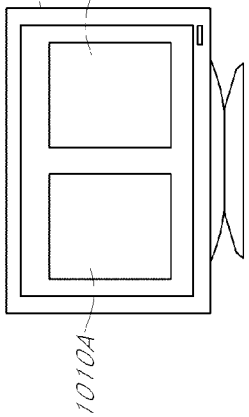


FIG. 10

SYSTEMS AND METHODS FOR INTERLEAVING SERIES OF MEDICAL IMAGES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 12/857,915, filed on Aug. 17, 2010 and titled "SYSTEMS AND METHODS FOR INTERLEAVING SERIES OF MEDICAL IMAGES," which is a continuation of U.S. patent application Ser. No. 11/268,261, filed on Nov. 3, 2005 and titled "SYSTEMS AND METHODS FOR INTERLEAVING SERIES OF MEDICAL IMAGES," which claims priority under 35 U.S.C. §119(e) to U.S. Provisional Application Ser. No. 60/625,690, filed on Nov. 4, 2004, each of which is hereby expressly incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to management and viewing of medical images and, more particularly, to systems and methods of comparing related medical images in order to detect differences in the compared images.

2. Description of the Related Art

Medical imaging is increasingly moving into the digital realm. This includes imaging techniques that were traditionally analog, such as mammography, x-ray imaging, angiography, endoscopy, and pathology, where information can now be acquired directly using digital sensors, or by digitizing information that was acquired in analog form. In addition, many imaging modalities are inherently digital, such as MRI, CT, nuclear medicine, and ultrasound. Increasingly these digital images are viewed, manipulated, and interpreted using computers and related computer equipment. Accordingly, there is a need for improved systems and methods of viewing and manipulating these digital images.

When comparison of related images is required, subtle differences between images may be difficult to detect. For example, if a lung radiograph from two months previous, and a current lung radiograph are to be compared in order to determine if any changes have occurred in the lungs over the previous two months, the viewer or reader typically views the two x-rays side by side. For example, the viewer or reader may have two monitors placed side by side, wherein each of the monitors displays a chest radiographic image. Alternatively, the viewer may view the two images side by side on a single monitor. However, as those of skill in the art will recognize, identifying differences in related images in this manner is often tedious and difficult. Some imaging modalities, such as CT and MRI, produce a large number of images, hundreds to even thousands of images per exam. In many cases, comparison of different series of images within the exam is required. For example, comparison of pre and post contrast images to detect areas of enhancement or comparison of PET and CT images for localization of activity is often necessary. Further, these often large exams may need to be compared to multiple prior exams to detect subtle, progressive changes over time, for example to detect a small, growing tumor. Current imaging software does not provide a satisfactory method for comparing images contained in two or more image series. Accordingly, systems and methods for comparison of images of multiple image series so that differences in the images may be more easily distinguishable are desired.

SUMMARY OF THE INVENTION

In one embodiment, a method of viewing medical images from two or more image series on a display device coupled to a computing device comprises the steps of selecting a first image series comprising two or more medical images, selecting at least one comparison image series, each of the comparison image series comprising two or more medical images, interleaving images of the first image series and the comparison image series in order to form an interleaved image series, and sequentially displaying the images of the interleaved image series at a single location on the display device.

In another embodiment, a method of viewing a series of medical images on a display device coupled to a computing device comprises the steps of (a) selecting a first image series for viewing, the first image series comprising a plurality X of medical images, (b) selecting a second image series for viewing, the second image series comprising a plurality Y of medical images, (c) displaying at a predetermined location on the display device a Nth image of the first image series, (d) replacing the Nth image of the first image series with a Mth image of the second image series at the predetermined location, (e) incrementing N and M, and (f) repeating steps (c) to (f).

In another embodiment, a system for enhancing a viewer's ability to detect differences between medical images in two or more sets of medial images comprises a display device, a graphical user interface displayed on the display device and comprising an image pane configured to display a single medical image at a time, an image selection module to select two or more sets of medical images, each of the sets of medical images comprising two or more medical images, and a user interface to receive commands from a user, wherein in response to receiving a first command from the user, the image pane sequentially displays a first medical image from each of the image sets and, after displaying the first medical image from each image set, the image pane sequentially displays a second medical image from each image set. This process of displaying images from images series alternatively continues through subsequent images in the image series.

In another embodiment, a system of viewing medical images from two or more image series on a display device coupled to a computing device comprises means for selecting a first image series comprising two or more medical images, means for selecting at least one comparison image series, each of the comparison image series comprising two or more medical images, means for interleaving images of the first image series and the comparison image series in order to form an interleaved image series, and means for sequentially displaying the images of the interleaved image series at a single location on the display device.

In another embodiment, a method of forming an interleaved image series comprises selecting N groups of images, each of the groups of images comprising two or more images, determining a starting image of each of the groups of images, creating an interleaved image series comprising images from each of the selected N groups of images, wherein the images of the interleaved image series are ordered so that an image from each of the N groups of images is included in each sequential Nth group of images,

and providing the interleaved image series to a user interface for sequential display in a predetermined location of a display device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an exemplary computing system in communication with a network and various networked devices.

FIG. **2** is a diagram illustrating a display device having images from two image series concurrently displayed in image panes displayed on a display device.

FIG. **3** is a diagram illustrating a display device having images from four image series concurrently displayed in image panes.

FIG. **4** is a diagram illustrating sequential changes to a comparison pane displayed on the display device as images from two image series are compared.

FIG. **5** is a diagram illustrating an exemplary interleaving of four image series.

FIG. **6** is a flowchart illustrating an exemplary method of viewing images from multiple image series.

FIGS. **7**A and **7**B are images of a first image series.

FIGS. **8**A and **8**B are images of a second image series.

FIGS. **9**A-**9**D are the images of the first and second image series interleaved for sequential viewing in a predetermined portion of a display.

FIG. **10** is a diagram illustrating a display device displaying two comparison panes.

FIG. **11** illustrates the first images of the first and second image series illustrated in FIGS. **7**A and **8**A interleaved for alternative viewing in a comparison pane.

FIG. **12** illustrates the second images of the first and second image series illustrated in FIGS. **7**B and **8**B interleaved for alternative viewing in a comparison pane.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Embodiments of the invention will now be described with reference to the accompanying figures, wherein like numerals refer to like elements throughout. The terminology used in the description presented herein is not intended to be interpreted in any limited or restrictive manner, simply because it is being utilized in conjunction with a detailed description of certain specific embodiments of the invention. Furthermore, embodiments of the invention may include several novel features, no single one of which is solely responsible for its desirable attributes or which is essential to practicing the inventions herein described.

FIG. **1** is a block diagram of an exemplary computing system **100** in communication with a network **160** and various network devices. The computing system **100** may be used to implement certain systems and methods described herein. The functionality provided for in the components and modules of computing system **100** may be combined into fewer components and modules or further separated into additional components and modules.

The computing system **100** includes, for example, a personal computer that is IBM, Macintosh, or Linux/Unix compatible. In one embodiment, the exemplary computing system **100** includes a central processing unit ("CPU") **105**, which may include a conventional microprocessor, an application module **145** that comprises one or more various applications that may be executed by the CPU **105**. The application module **145** may include, by way of example, components, such as software components, object-oriented software components, class components and task components, processes, functions, attributes, procedures, subroutines, segments of program code, drivers, firmware, microcode, circuitry, data, databases, data structures, tables, arrays, and variables.

The computing system **100** further includes a memory **130**, such as random access memory ("RAM") for temporary storage of information and a read only memory ("ROM") for permanent storage of information, and a mass storage device **120**, such as a hard drive, diskette, or optical media storage device. Typically, the modules of the computing system **100** are connected to the computer using a standards-based bus system. In different embodiments of the present invention, the standards based bus system could be Peripheral Component Interconnect (PCI), Microchannel, SCSI, Industrial Standard Architecture (ISA) and Extended ISA (EISA) architectures, for example.

The computing system **100** is generally controlled and coordinated by operating system software, such as the Windows 95, 98, NT, 2000, XP or other compatible operating systems. In Macintosh systems, the operating system may be any available operating system, such as MAC OS X. In other embodiments, the computing system **100** may be controlled by a proprietary operating system. Conventional operating systems control and schedule computer processes for execution, perform memory management, provide file system, networking, and I/O services, and provide a user interface, such as a graphical user interface ("GUI"), among other things.

The exemplary computing system **100** includes one or more of commonly available input/output (I/O) devices and interfaces **110**, such as a keyboard, mouse, touchpad, and printer. In one embodiment, the I/O devices and interfaces **110** include one or more display devices, such as a monitor, that allows the visual presentation of data to a user. More particularly, display devices provide for the presentation of GUIs, application software data, and multimedia presentations, for example. In one embodiment, a GUI includes one or more image panes in which medical images may be displayed. As described in further detail below, a GUI may provide a comparison pane on a display device in which images from multiple image series are sequentially displayed. According to the systems and methods described below, medical images may be stored on the computing system **100** or another device that is local or remote, displayed on a display device, and manipulated by the application module **145**. The computing system **100** may also include one or more multimedia devices **140**, such as speakers, video cards, graphics accelerators, and microphones, for example.

In the embodiment of FIG. **1**, the I/O devices and interfaces **110** provide a communication interface to various external devices. In the embodiment of FIG. **1**, the computing system **100** is coupled to a network **160**, such as a LAN, WAN, or the Internet, for example, via a communication link **115**. The network **160** may be coupled to various computing devices and/or other electronic devices. In the exemplary embodiment of FIG. **1**, the network **160** is coupled to imaging devices **170**, an image server **180**, and a medical facility **190**. In addition to the devices that are illustrated in FIG. **1**, the network **160** may communicate with other computing, imaging, and storage devices.

The imaging devices **170** may be any type of device that is capable of acquiring medical images, such as a MRI, x-ray, mammography, or CT scan systems. The image server **180** includes a data store **182** that is configured to store images and data associated with images. In one embodi-

ment, the imaging devices **170** communicate with the image server via the network **160** and image information is transmitted to the image server **160** and stored in the data store **182**. In one embodiment, the image data is stored in Digital Imaging and Communications in Medicine ("DICOM") format. The complete DICOM specifications may be found on the National Electrical Manufactures Association Website at <medical.nema.org>. Also, *NEMA PS3—Digital Imaging and Communications in Medicine,* 2004 ed., Global Engineering Documents, Englewood Colo., 2004, provides an overview of the DICOM standard. Each of the above-cited references is hereby incorporated by reference in their entireties. In one embodiment, the data store **182** also stores the user-defined display parameters associated with one or more of the images stored on the data store **182**. As discussed in further detail below, the user-defined display parameters may vary depending of the type of image, area imaged, clinical indication, source of image, display device, user, or other factors. Accordingly, any type of user-defined display parameter is expressly contemplated for use in conjunction with the systems and methods described herein.

The exemplary image server **180** is configured to store images from multiple sources and in multiple formats. For example, the image server **180** may be configured to receive medical images in the DICOM format from multiple sources, store these images in the data store **182**, and selectively transmit medical images to requesting computing devices.

The medical facility **190** may be a hospital, clinic, doctor's office, or any other medical facility. The medical facility **190** may include one or more imaging devices and may share medical images with the image server **180** or other authorized computing devices. In one embodiment, multiple computing systems, such as the computing system **100** may be housed at a medical facility, such as medical facility **190**.

DEFINITION OF TERMS

"Medical image" is defined to include an image of an organism. It may include but is not limited to a radiograph, computed tomography (CT), magnetic resonance imaging (MRI), Ultrasound (US), mammogram, positron emission tomography scan (PET), nuclear scan (NM), pathology, endoscopy, ophthalmology, or many other types of medical images. While this description is directed to viewing and tracking of medical images, the methods and systems described herein may also be used in conjunction with non-medical images, such as, images of circuit boards, airplane wings, and satellite images, for example.

"Modality" is defined as a medical imaging device (a patient who undergoes an MRI is said to have been scanned with the MRI modality).

"Image series" refers to two or more images that are related. For example, an image series may comprise two or more images of a particular patient that are acquired on a particular date, e.g., different x-ray projections of the chest. A series of contiguous 3 mm axial CT scans of the chest would be another example of an image series. A brain MRI scan might include the following series: sagittal T1 weighted images, axial T1 weighted images, axial FLAIR images, axial T2 weighted images, as well as post contrast axial, sagittal and coronal T1 weighted series. An image series may be limited to images of a certain modality or may comprise images of multiple modalities.

"Patient" refers to an individual who undergoes a medical imaging examination.

"Display parameters" are defined to include methods of display of an image or exam. Display parameters may include, for example, a pixel window level and width (similar to brightness and contrast), a certain color map that renders different pixel intensities as different colors, or opacity map.

"Interleaving," is defined to include the process of arranging images from multiple image series by regularly alternating between images of the multiple image series in order to create a resultant "interleaved" image series. In one embodiment, an interleaved image series comprises images from multiple image series ordered so that the interleaved image series alternates between the images of the original series. For example, when image series A comprising images A1, A2, . . . An, image series B comprising images B1, B2, . . . Bn, and image series C comprising images C1, C2, . . . Cn are interleaved, the resultant interleaved image series is ordered: A1,B1,C1,A2,B2,C2, . . . An,Bn,Cn. Images from multiple image series may be interleaved in various patterns and multiple interleaved image series may be generated from two or more image series.

FIG. **2** is a diagram illustrating a display device having images from two image series concurrently displayed in image panes **212**, **214** displayed on a display device **210**. In the discussion that follows, the display device **210** is coupled to a computing device, such as computing device **100**, and receives display information from the computing device **100**. While the systems and methods described below for interleaving and viewing images of multiple image series may be controlled by any suitable computing device, for ease of explanation herein, reference will be made to a display device coupled to computing device **100**.

In the embodiment of FIG. **2**, an image of a series A image series is displayed in the image pane **212**, while an image of the series B image series is displayed in the image pane **214**. As noted above, each image series comprises a group of images that are related in some way, such as having been acquired from a patient on a particular day. Although only a single image of each of the image series is simultaneously displayed on the display device **210**, the series A and series B image series each comprise multiple images.

In certain embodiments, such as where the series A and B images are related, e.g., series A comprises mammogram images of a patient taken on a first date and series B comprises the mammogram images of the same patient taking on a later date, it may be advantageous to identify differences between the images of Series A and Series B. However, as described above, it is difficult to distinguish minor or small differences between images using currently available image comparison techniques. Using current image comparison systems, if a lung radiograph from two months previous, and a current lung radiograph are to be compared in order to determine if any changes have occurred in the lungs over the previous two months, the viewer or reader typically views the two x-rays side by side, such as in image panes **212**, **214** illustrated in FIG. **2**. As those of skill in the art will recognize, identifying differences in related images in this manner is often tedious and difficult. Accordingly, described hereinafter are exemplary systems and methods for comparison of images of multiple image series so that differences between (in contrast to within) the images may be more easily distinguishable. In certain embodiments, related images are displayed sequentially in a single viewing pane on a display device so that difference between the images may be more easily detected. The

systems and methods described herein are applicable to any two or more images, including multiple images of multiple image series, for example.

FIG. **3** is a diagram illustrating a display device having images from four image series concurrently displayed in image panes **312**, **314**, **316**, in **318**. In the embodiment of FIG. **3**, the image pane **312** displays images from series A, the image pane **314** displays images from series B, the image pane **316** displays images from series C, and the image pane **318** displays images from series D. Thus, a single image from each of the four image series A-D is concurrently displayed on the display device **210**. In certain prior art systems, comparison of images of multiple series was performed using a graphical user interface such as displayed in FIG. **3**, wherein the user distinguishes differences between images that are displayed side-by-side on a display device.

FIG. **4** is a diagram illustrating sequential changes to a comparison pane **410** displayed on the display device **210** as images from two image series are compared. The comparison pane **410** is configured to display a single image. In one embodiment, one of the display panes, e.g. display pane **312** on display device **210**, serve as the comparison pane **410**. In the embodiment of FIG. **4**, images from two image series, images series A and B, have been selected for comparison. After being selected for comparison using any suitable selection method, images from series A and B are interleaved so that they are alternatively displayed in the comparison pane **410**.

In embodiments with more than two series, the interleaved images may be ordered according to various schemes. For example images from four image series may be ordered as follows: first image of first image series, first image of second image series, first image of third image series, first image of fourth image series, second image of first image series, and so forth. In other embodiments, however, the interleaved images may be ordered differently. For example, images from four image series may also be ordered as follows: first image of first image series; first image of second image series; first image of first image series; first image of third image series; first image of first image series; and first image of fourth image series. Any other ordering of images from multiple image series falls within the scope of "interleaving" as used herein.

FIG. **4** shows the display device **210** at four steps **402**, **404**, **406**, **408** of the comparison process, where the comparison process describes the process of displaying images in an interleaved image series. More particularly, in step **402**, a first image of image series A is displayed in the comparison pane **410**. Moving to step **404**, the first image of image series A is replaced by a first image of image series B in the comparison pane **410**. Assuming the images of series A and B are of the same subject, the image displayed in steps **402** and **404** may be very similar. Accordingly, if differences exist in the first images of series A and B, these differences may be more easily detectable as the display device cycles between the two images. Comparison of images in an interleaved image series may be more advantageous if the images of each selected image series are of a common anatomical area, common image size, common image orientation, and the images are in the same order.

In one embodiment, the computing system **100** that is coupled to the display **210** may store settings for displaying images of particular image series, such as, for example, time for displaying each image, resolution of each image, cropping to be applied to each image, and any other setting that maybe appropriate. In one embodiment, the time for displaying an image may be determined real time by the user. For example, the user may press a designated key on a keyboard or mouse in order to indicate that the current image should be replaced with an adjacent image in the interleaved image series. In another embodiment, the user selects settings for display of the images. For example, the user may select an appropriate zoom level of an image series that should be applied to each image in the image series.

Thus, the images of series A may be magnified more or less than the images of series B. In addition, the user may adjust any other visualization settings for individual images, an entire image series, or two or more image series.

With the first image of series B displayed in the comparison pane **410** (step **404**), the user may initiate viewing of an adjacent image in the interleaved image series by pressing a certain key on a keyboard or mouse, for example. In one embodiment, a first input from a mouse indicates that a next image, e.g. image **2** of series A (step **406**) should be displayed in the comparison pane **410** and a second input from the mouse indicates that a previous image, e.g. image **1** of series A (step **402**) should again be displayed in the comparison pane **410**. In one embodiment, the first input is entered by the user moving a scroll button on the mouse in a first direction and the second input is entered by the user moving the scroll button on the mouse in an opposite direction. Thus, the user may change the content of the comparison pane **410** to either a next or a previous image in the interleaved image series. For example, at step **404**, if the user wishes to again view the first image of series A, e.g., in order to locate difference in the first images of series A and B, the user may provide an input to the computing device **100** indicating movement to a previous image. Alternatively, at step **404**, if the user wishes to view a next image in the interleaved image series, the user may provide an input to the computing device **100** indicating movement to a next image.

At step **406**, the second image of series A is displayed in the comparison pane **410**, replacing the first image of series B (step **404**). At step **406**, the user may provide inputs to the computing device **100** indicating that the comparison pane **410** should be updated with a previous image, e.g. step **404**, or a subsequent image, e.g., step **408**.

At step **408**, the second image of series B is displayed in the comparison pane **410**, replacing the second image of series B (step **406**). At step **406**, the user may provide inputs to the computing device **100** indicating that the comparison pane **410** should be updated with a previous image, e.g. step **404**, or a subsequent image. In one embodiment, each of the image series A and B include more than two images, such as 3 or more images, and the images of series A and B are displayed in the manner described above with respect to FIG. **4**. In one embodiment, more than two images series may be interleaved for display in the comparison pane. For example, if three images series, e.g., series A, B, and C, are selected for comparison, a first image of each of the series will be sequentially displayed in the comparison pane, followed by a second image of each of the series, and so on. As noted above, the user may control the timing of transition between display of images in the interleaved image series and may even control the direction of movement in the interleaved series. Additionally, the user may control alignment and/or positioning of the images of each images series in order to precisely align interleaved images from multiple series.

In one embodiment, the images of each of the image series are automatically modified so that characteristics of the images are similar. For example, images may be adjusted by changing their size, rotation, and location. If the images

are of substantially the same anatomical structure, when the images of the interleaved image series are displayed in the comparison pane, differences between adjacent images may be more easily detected. In one embodiment, selected images are morphed in order to achieve a common size of the anatomical structure of interest in each of the images. In one embodiment, photographic filters may be applied to all images of one or more image series, or to selected images of one or more image series, to further enhance the viewer's ability to distinguish differences in the images.

In one embodiment, information regarding the image currently displayed in the comparison pane **410** is displayed on the display device **210** and updated as the images in the comparison pane **410** are changed. For example, information regarding the images series and image number within the series may be displayed for each image. In addition, the exam date and time may also be displayed and updated as the images of the interleaved image series are displayed in the comparison pane **410**. In one embodiment, an indicator of whether the current display is of an interleaved image series or a single image series is displayed on the display device. For example, "interleaved" may be displayed at the top of the display device when an interleaved image series is displayed in a comparison pane. In some embodiment, the user chooses what information related to the images of the interleaved image series should be displayed. The user may also be provided the ability to turn the display of information on and off, such as by pressing a particular key or key combination on the keyboard.

FIG. **5** is a diagram illustrating an exemplary interleaving of four image series in creating an interleaved image series. As noted above, the image series that are selected for comparison, and thus, are selected for interleaving, may be selected by a user in one of several manners or may be automatically selected by the computing device based on properties of the image series. In one embodiment, the multiple image series are interleaved so that a first image of each series is displayed in the comparison pane prior to display of a second image of any of the other selected image series. FIG. **5** illustrates an exemplary interleaving of four image series, series A, B, C, and D, each comprising four images. As those of skill in the art will recognize, more or less image series, each comprising more or less images, may be interleaved in a manner similar to that illustrated in FIG. **5**.

In FIG. **5**, the images of series A are represented by diamonds in a column **510**, where a number in each of the diamonds represents a specific image within image series A. Similarly, images of series B are represented by squares in column **520**, series C are represented by ovals in a column **530**, and series D are represented by parallelograms in a column **540**. Each of the images in images series B, C, and D are likewise numbered 1-4, indicating a particular image in each image series. As noted above, the first image selected for comparison in a particular image series may not be the first image in the image series, e.g., the first image of an exam. Thus, although each image series A-D begins with a first image labeled image "1", this first image may not be the first image in the image series, but may be a user selected, or automatically selected, start image. In addition, each of the images may have user-defined display parameters that are different than other images of the same series and/or other image series. In some embodiments, display parameters, such as zoom level, cropping, and color characteristics, may be simultaneously changed for each image in an image series, such as series A, B, C, D, or an interleaved image series, such as interleaved image series **540**.

As illustrated in FIG. **5**, an interleaved image series **550** each of the images 1-4 in each of the image series A-D. More particularly, the interleaved image series **550** comprises a first image from each of series A-D, followed by a second image from each of the series A-D, followed by a third image from each of the series A-D, followed by a fourth image from each of the series A-D. Thus, when the interleaved image series **550** is displayed in the comparison pane, a first image of the image series A is displayed, followed by a first image of image series B, a first image of image series C, and a first image of image series D. While the order of the interleaved image series **550** is maintained during viewing of the interleaved images, the direction of movement between adjacent images may be selected by the user or automatically by the computing device **100**.

FIG. **6** is a flowchart illustrating an exemplary method of viewing images from multiple image series. Using the method of FIG. **6**, multiple image series may be easily compared and differences between images of the multiple image series may be distinguished.

In a block **610**, a first image series is selected. As noted above, an image series is a group of two or more images that are in some way related. For example, a first image series may comprise multiple chest x-rays of a patient that are taken on a given date.

In a block **620**, one or more comparison image series are selected. These image series also each comprise two or more images that are in some way related, such as having been taken at a common exam. The comparison image series should be related to the first image series so that when the first image series and the comparison image series are compared, meaningful distinctions between the image series may be detected.

In one embodiment, the first image series and the comparison image series are selected by the user clicking on a button indicating that image interleaving is desired. In one embodiment, a user right-clicks with a mouse on an image of a first image series in order to initiate display of an "interleave menu" listing options for selecting image series for interleaving and viewing the interleaved image series. In one embodiment, the interleave menu includes an option, such as "interleave adjacent," indicating that the user may select one of the other image series displayed on the display for interleaving. In certain embodiments, any number of image panes may be simultaneously displayed on the display device **210**. For example, in FIG. **2**, two image panes **212**,**214** are display and in FIG. **3**, four image panes **312**, **314**, **316**, **318** are displayed. In other embodiment, six, eight, ten, twelve, or more image panes may be concurrently displayed on the display device.

When the interleave adjacent option is selected, the user may select one or more comparison series by moving the pointer to a border between the adjacent series and clicking the mouse button. In one embodiment, the cursor icon changes when it is positioned in a border indicating that the adjacent image series may be selected for comparison by clicking the mouse button. With reference to FIG. **3**, for example, the user may right click on the image pane **314** in order to select series B as the first image series and to initiate display of the interleave menu. From the interleave menu, if the user selects interleave adjacent, the user may then move the pointer to the border between the image panes **312** and **314** and click the mouse button in order to select series A as a comparison image series. In one embodiment, selecting a comparison image series initiates creation of an interleaved image series and displays the first image of the interleaved image series in the comparison pane. In an embodiment

when only two image series are represented on the display device, such as FIG. **2**, selection of interleave adjacent from the interleave menu may automatically select the two displayed image series for interleaving and initiate creation and viewing of a interleaved image series.

In one embodiment, the interleave menu also includes an option that allows the user to select an adjacent image series for interleaving and, after selection of the first and comparison image series, displays images of the interleaved images series in a comparison pane that covers the entire display area, or substantially all of the display area, of the display device. In this way, the images of the selected image series may be viewed at a higher magnification level and, accordingly, differences in the images may be more easily detectable. Thus, in an embodiment that displays four image panes on the display device (e.g., FIG. **3**), after selection of this option from the interleave menu, a single click on a comparison image series may cause the computing device to generate an interleaved image series and display a first image of the interleaved image series in a comparison pane that covers substantially all of the display area of the display device, e.g., the area previously covered by the four image panes **312**, **314**, **316**, **318** or FIG. **3**. Advantageously, this "interleave and jump to full screen display" option on the interleave menu provides an efficient transition from display of many image series to the display of a single interleaved series in a comparison pane that covers all, or substantially all, of the display area of a display device.

In one embodiment, the interleave menu includes an option that initiates automatic selection of one or more comparison image series based upon characteristics of the selected first image series. For example, image series with the same or similar names may be selected as comparison image series. In addition, image series may be selected automatically based upon any other criteria, such as one or more information items contained in the DICOM headers of images. In one embodiment, when this option is chosen from the interleave menu, a list of image series that have the same series name, or other criteria that may be user defined, may be displayed. The user may then select one or more of the displayed series as comparison image series.

The interleave menu advantageously allows the user to select image series for interleaving and automatically display the generated interleaved image series with minimal input from the user. For example, after selecting "interleave adjacent" on the interleave menu, a single click of a mouse, for example, on a border between the images to be interleaved causes the computing system **100** to generate an interleaved image series and display a first image of the interleaved image series in a comparison pane on the display device.

Returning to the diagram of FIG. **6**, in a block **630**, a starting image of each of the image series is selected. In one embodiment, a first image of the first image series and each of the comparison image series are displayed on a display device. A user, using an input device, such as a mouse or keyboard, may cycle through the images in each of the image series in order to determine a first image for comparison. For example, images of certain modalities, such as CT and MRI images, may not have starting images that are each taken at similar physical locations within the patient. Thus, in these embodiments the user may select a different starting image in each of the image series so that adjacent images in the interleaved image series are more closely related. For example, if the images series to be interleaved are series A comprising images A1, A2, . . . An, series B comprising images B1,B2, . . . Bn, and series C comprising images C1, C2, . . . Cn, the user may select images A1, B3, and C5 as the starting images of the respective image series so that the resultant interleaved image series is ordered A1,B3,C5, A2,B4,C6, A3,B5,C7, . . . Ax,Bx+2,Cx+4.

In an advantageous embodiment, the starting image in each of the series should be related so that meaningful differences between the images of the image series are detectable. In one embodiment, the user may adjust display characteristics of each image in an image series by adjusting the display characteristics of the image currently displayed from the desired image series. For example, if the first image series is at a higher zoom level than the comparison image series, the zoom level of each image in the first image series may be adjusted by adjusting the zoom level of the currently display image of the first image series.

After selecting the first image series and the comparison image series, and selecting the display characteristics of one or more of the images which are then applied to the other images in the series to which it belongs, the image series are interleaved so that an interleaved image series is created, as illustrated in FIG. **5**, for example.

In a block **640**, images from the interleaved image series are displayed in a comparison pane displayed on the display device. In one embodiment, the comparison pane fills substantially the entire display area of a display device. In another embodiment, the comparison pane is smaller than a total display area of the display device. In one embodiment, a user input determines when a current image displayed in the comparison pane is updated with an adjacent image, by moving a scroll wheel on a mouse while pressing a mouse button, for example. In one embodiment, when the user has completed viewing the interleaved image series, the previous layout on the display device may be restored by the user performing a specific action, such as releasing the mouse button that is depressed while viewing interleaved images.

FIGS. **7**A and **7**B are images of a first image series, FIGS. **8**A and **8**B are images of a second image series, and FIGS. **9**A-**9**D are the images of an interleaved image series comprising images of the first and second image series. More particularly, FIGS. **7**A and **7**B are two mammographic images **710**, **720** in a first image series. In one embodiment, the images **710**, **720** are of a patient on a first date. FIGS. **8**A and **8**B are two mammographic images **810**, **820** in a second image series. In one embodiment, the images **710**, **720**, **810**, **820** are of the same patient, but the images **810**, **820** were taken at a later date than the images **710**, **720**. Thus, differences between the earlier mammographic images **710**, **720** and the later mammographic images **810**, **820** may be useful in detection and diagnosis of the patient. Accordingly, comparison of the images of the images series illustrated in FIGS. **7** and **8** may allow detection of differences between the earlier and later images.

FIGS. **9**A-**9**D are the images of FIGS. **7** and **8** combined in an interleaved image series for viewing in a comparison pane. For example, image **710** may first be displayed in a comparison pane. When the user indicates that a next image should be displayed, image **810** may replace image **710** in the comparison pane. With image **810** displayed in the comparison pane, when the user indicates that a next image should be displayed, image **720** is replaced with image **810** in the comparison pane. With image **720** displayed in the comparison pane, when the user indicates that a next image should be displayed, image **720** is replaced with image **820** in the comparison pane. As noted above, however, movement between images in an interleaved image series, such as that of FIG. **9**, may be bidirectional so that the user may move back and forth between images as desired.

In another embodiment, interleaving of image series produces two or more interleaved image series. In one embodiment, the first image of each image series may be interleaved and alternatively displayed in a first comparison pane of the display device, while the second image of each image series may be interleaved and alternatively displayed in a second comparison pane of the display device, and so on. For example, if the image series to be interleaved are series A comprising images A1, A2, and series B comprising images B1,B2, the system may generate a first interleaved series ordered A1, B1, and a second interleaved image series ordered A2, B2. In one embodiment, images from each from each of the first and second interleaved image series are concurrently displayed on a display device in separate comparison panes. In one embodiment, an option on the interleave menu, discussed above, may be selected in order to initiate generation of multiple interleaved image series and concurrent display of multiple comparison panes on the display device. In one embodiment, more than two images of image series may be interleaved in the above-described manner and more than two comparison panes may be displayed concurrently on a display device for viewing the generated interleaved image series.

FIG. **10** is a diagram illustrating the display device **210** having two comparison panes **1010**A, **1010**B. As noted above, multiple interleaved image series may be concurrently displayed on the display device **210** in separate comparison panes. In another embodiment, the display device **210** displays three or more comparison panes for concurrently displaying three or more interleaved image series.

FIG. **11** illustrates the first images **710**, **810** of the first and second image series illustrated in FIGS. **7**A and **8**A and FIG. **12** illustrates the second images **720**, **820** of the first and second image series illustrated in FIGS. **7**B and **8**B. The images **710**, **810** (FIG. **11**) comprise a first interleaved image series, while the images **720**, **820** (FIG. **12**) comprise a second interleaved image series. In the embodiment illustrated in FIGS. **11** and **12**, the images **710**, **720** are from a first exam and the images **810**, **820** are from a second exam. However, the first selected images from each exam, e.g., images **710**, **810**, are of a first projection, while the second selected images from each exam, e.g., **720**, **820**, are of a second projection. Thus, it may be advantageous for an interpreter of the images to view the images of the same projection, from different exams, in separate interleaved image series. Accordingly, in the embodiment of FIGS. **10**, **11**, and **12**, a first interleaved image series comprising images **710**, **810** are viewed in a first comparison pane **1010**A while a second interleaved image series comprising images **720**, **820** are viewed in a second comparison pane **1010**B. In this embodiment, the viewer may advantageously move between images of the same projection in a comparison pane in order to identify differences in the images, while also viewing images of one or more additional projections in additional comparison panes. In one embodiment, any number of images may be included in each of the interleaved images series displayed in comparison panes **101**A, **1010**B, and additional comparison panes may be concurrently displayed on the display device **210**.

The foregoing description details certain embodiments of the invention. It will be appreciated, however, that no matter how detailed the foregoing appears in text, the invention can be practiced in many ways. As is also stated above, it should be noted that the use of particular terminology when describing certain features or aspects of the invention should not be taken to imply that the terminology is being re-defined herein to be restricted to including any specific characteristics of the features or aspects of the invention with which that terminology is associated. The scope of the invention should therefore be construed in accordance with the appended claims and any equivalents thereof.

What is claimed is:

1. A method comprising:

receiving, at a computing system, at least a first plurality of images comprising a first image series and a second plurality of images comprising a second image series, wherein the first plurality of images and the second plurality of images together comprise a set of images;

analyzing, by the computing system, the set of images to identify anatomical positions associated with respective images of the set of images;

determining, by the computing system, at least a second characteristic associated with each of the images of the set of images;

determining, by the computing system, an ordering of the images of the set of images based on:

first: anatomical positions associated with respective images of the set of images, and

second: values of the second characteristic associated with respective images of the set of images;

displaying at a location of a display a first image of the set of images that is first in the determined ordering of the images; and

in response to input from a user of the computing system indicating a direction of movement within the set of images, replacing, at the location, the first image with a second image, wherein the second image is adjacent to the first image in the ordering of the images.

2. The method of claim **1**, wherein said analyzing comprises determining the anatomical positions by reference to a header.

3. The method of claim **1**, wherein the ordering of the images is further determined based on at least one of a type of image, an area imaged, a clinical indication, a source of image, a display device, or a user.

4. The method of claim **1**, wherein the ordering of the images is further determined based on at least one of brightness, contrast, size, opacity map, rotation, location, zoom level, cropping, morphing, or color of the images.

5. The method of claim **1**, wherein the second characteristic comprises a time at which the respective images of the set of images was obtained.

6. The method of claim **1** further comprising:

automatically adjusting, by the computing system, at least one characteristic associated with the first image of the set of images such that the first image is better aligned with the second image of the set of images.

7. The method of claim **1**, wherein a display characteristic of the second image is adjusted such that the information displayed in the first image and the second image more closely matches, and differences between the first image and the second image are more easily detectable by the user.

8. The method of claim **7**, wherein the display characteristic comprises at least one of brightness, contrast, size, opacity map, rotation, location, zoom level, cropping, morphing, or color.

9. The method of claim **1**, wherein the computing system is configured to provide the input in response to the user moving a scroll wheel of a mouse or other input device in a first direction.

10. The method of claim **1** further comprising:

in response to a second input from the user of the computing system indicating an opposite direction of

movement within the set of images, replacing, at the location, the second image with the first image.

11. The method of claim **10**, wherein the computing system is configured to provide the second input in response to the user moving a scroll wheel of a mouse or other input device in a first direction.

12. The method of claim **11**, wherein the computing system is configured to provide the second input in response to the user moving a scroll wheel of a mouse or other input device in a second direction.

13. The method of claim **1** further comprising:

determining, by the computing system, a characteristic associated with the first image series;

identifying, by the computing system, the second image series for comparison with the first image series, wherein the second image series is identified based on the second image series being associated with the same characteristic as the first image series.

14. The method of claim **13**, wherein the characteristic associated with the first image series comprises at least one of a header information item, a filename, or a modality.

15. The method of claim **1**, further comprising in response to another input from the user of the computing system indicating the direction of movement within the set of images, replacing, at the location, a third image in the images of the set of images with another image of the set of images that is adjacent to the third image in the ordering of the images.

16. A computing system comprising:

an electronic display;

an input device;

a non-transitory computer-readable storage medium configured to store software instructions; and

one or more computer processors in communication with the electronic display, the input device, and the non-transitory computer-readable medium, the one or more computer processors configured to execute the software instructions in order to cause the computing system to:

receive at least a first plurality of images comprising a first image series and a second plurality of images comprising a second image series, wherein the first plurality of images and the second plurality of images together comprise a set of images;

analyzing, the set of images to identify anatomical positions associated with respective images of the set of images;

determine at least a second characteristic associated with each of the images of the set of images;

determine an ordering of the images of the set of images based on:

first: anatomical positions associated with respective images of the set of images, and

second: values of the second characteristic associated with respective images of the set of images;

display at a location of a display a first image of the set of images that is first in the determined ordering of the images; and

in response to input from a user of the computing system indicating a direction of movement within the set of images, replace, at the location, the first image with a second image, wherein the second image is adjacent to the first image in the ordering of the images.

17. A method comprising:

receiving, at a computing system, at least a first plurality of images comprising a first image series and a second plurality of images comprising a second image series, wherein the first plurality of images and the second plurality of images together comprise a set of images;

analyzing, by the computing system, the set of images to identify values of a first characteristic associated with respective images of the set of images, wherein the first characteristic comprises at least one of a modality or an application of contrast agent;

determining, by the computing system, at least a second characteristic associated with each of the images of the set of images;

determining, by the computing system, an ordering of the images of the set of images based on:

first: values of the first characteristic associated with respective images of the set of images, and

second: values of the second characteristic associated with respective images of the set of images;

displaying at a location of a display a first image of the set of images that is first in the determined ordering of the images; and

in response to input from a user of the computing system indicating a direction of movement within the set of images, replacing, at the location, the first image with a second image, wherein the second image is adjacent to the first image in the ordering of the images.

18. The method of claim **17**, wherein the second characteristic comprises a time at which the respective image of the set of images was obtained.

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